P2.34   AUTOMATIC JET CONTRAIL DETECTION AND SEGMENTATION

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1. INTRODUCTION

Jet contrails are an important subset of cirrus clouds in the atmosphere, and thin cirrus are thought to enhance the greenhouse effect due to their semi-transparent nature. They are nearly transparent to the solar energy reaching the surface, but they reduce the planetary emission to space due to their cold ambient temperatures.

Having "seeded" the environment, contrails often elongate and widen into cirrus-like features. However, there is great uncertainty regarding the impact of contrails on surface temperature and precipitation. With increasing numbers of subsonic aircraft operating in the upper troposphere, there is the possibility of increasing cloudiness which could lead to changes in the radiation balance. Automatic detection and segmentation of jet contrails in satellite imagery is important because (1) it is impractical to compile a contrail climatology by hand, and (2) with the segmented images it will be possible to retrieve contrail physical properties such as optical thickness, effective ice crystal diameter and emissivity.

2. DATA

Advanced Very High Resolution Radiometer (AVHRR) Local Area Coverage (LAC) satellite data at 1.1km spatial resolution at nadir is used in this investigation. In particular, AVHRR channels 4 and 5, centered at 10.8 μm and 12.0 μm, respectively, are used to create a difference channel in which most features in the background are suppressed, making contrail detection much easier. In this difference image, contrails are characterized as thin, nearly straight linear features of higher intensity than the background. Such thin features are known as ridges.

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3. METHODOLOGY

The first step in contrail detection and segmentation is ridge detection. A ridge is a connected linear structure that is long relative to its width, with a skeleton along which the pixel intensities change slowly. Ridge points are brighter than the surrounding background in at least two directions. The ridge-finding algorithm examines a 6x6 pixel neighborhood for ridges. This procedure greatly enhances the ridges created by jet contrails and eliminates much clutter in the difference image (Engelstad et al. 1992).

Not all ridges are caused by contrails. Some are caused by thin cirrus streaks and other natural image features. Jet contrails have the additional property of forming straight line segments in satellite imagery, unlike most natural image features.

Once the ridge detection is complete, a linear Hough Transform is applied to detect lines in the image. A list of straight line segments is produced that are approximately coincident with the contrails. However, contrails are not often one pixel wide. In some places, they may have spread to be several pixels wide; in others, the contrail may not be visible. Furthermore, the contrail may not be exactly collinear with the Hough line segment. Additional processing is required for segmentation, even after the Hough transform has successfully detected image contrails.

The approach to segmentation applied here is called searching near an approximate location. The cross-section of a ridge has a characteristic profile that resembles a Gaussian curve. We make use of this characteristic ridge cross-section for searching. Figure 1a shows a horizontal segment through a channel 4-5 difference image that crosses four contrails, and Figure 1b shows the intensity profile along this segment. A local maximum (peak) is found, with pixel intensities which drop off on either side of the ridge, eventually reaching the level of the surrounding background. After locating the peak, an examination is made of difference between adjacent pixel intensities along the perpendicular. All pixels between the end of the intensity drop-offs on the two sides of the ridge are marked as contrail pixels.
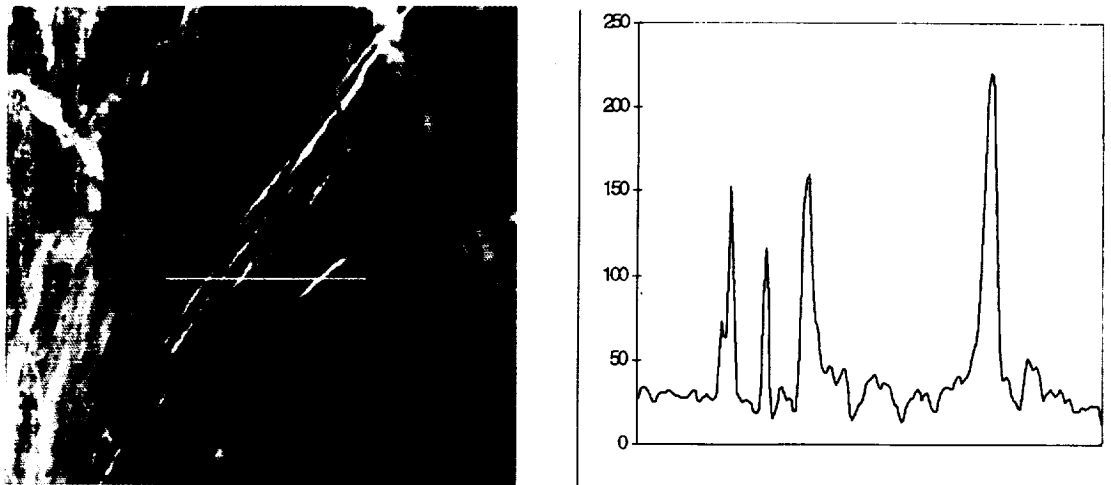
Figure 1. (a) AVHRR contrail image (channel 4-5 difference). Horizontal line yields the intensity profile. (b) Intensity profile showing ridge-like structures that correspond to contrails in the image.

4. RESULTS

Figure 2 a-c shows three channel 4-5 difference images containing contrails, and Fig 2 d-f show the detected segmented contrails overlaid onto these images. As can be seen, the detection and segmentation algorithm is robust in discriminating the majority of contrails in these scenes, without human intervention. In most cases, clutter in the image is rejected, even cirrus streaks. False detections are labeled as "A" and "C" in Fig. 2. However, some contrails may be missed because they are curved, diffused over such a large area that the ridge detector is ineffective (labeled as "B" in Fig. 2), or present in short segments that may be missed by the Hough line detector. Long, thin contrails are most easily detected and segmented with the present algorithm. Increased contrail detection may be achieved, but only at the cost of increasing false alarms (cirrus streaks). Decreasing the number of false alarms necessarily eliminates some faint contrails.
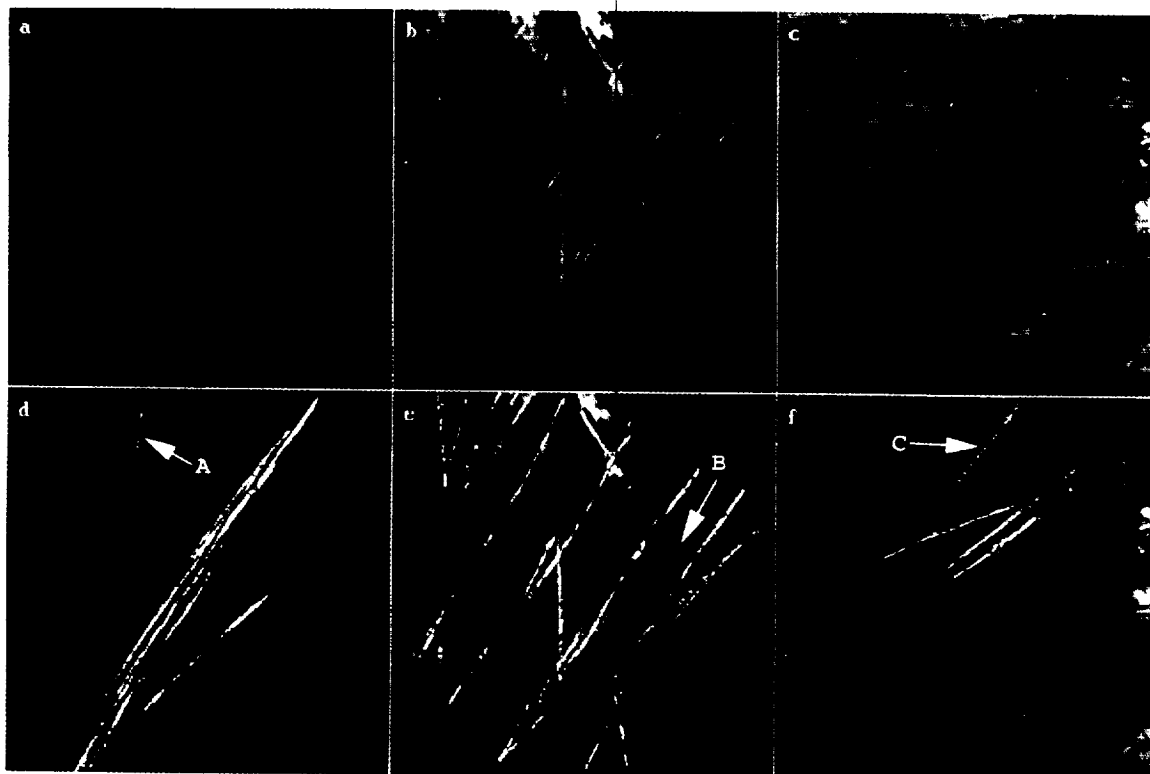

Figure 2. (a-c) Three channel 4-5 difference images; (d-f) Images with contrails overlaid.

Neglecting large, diffuse contrails, Fig. 3 shows that contrails on average have widths of about 2-3 pixels (i.e., 2-3 km), in agreement with Detwiler and Pratt (1984). The algorithm is robust and efficient, with CPU times on the order of 12 seconds on an Intel 486-66 computer to process 512x512 pixel regions.
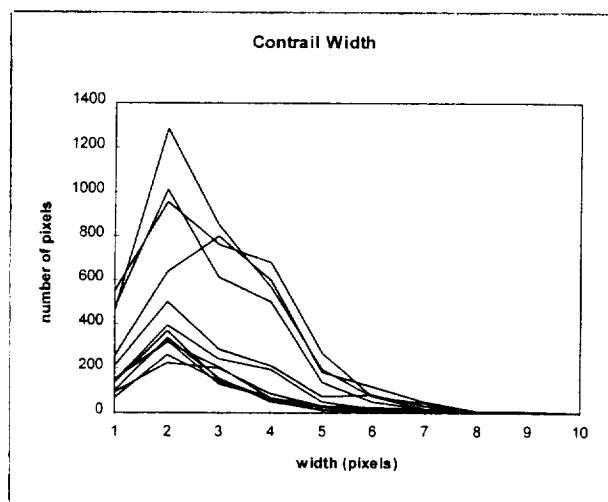

Figure 3. Histogram of contrail widths in 12 AVHRR scenes.

Now that segmentation is achievable, contrail physical properties may be retrieved, such as optical thickness, effective particle size and emissivity.

References

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Engelstad, M, S. K. Sengupta, T. Lee and R. M. Welch, 1992: Automated detection of jet contrails using the AVHRR split window, *Int. J. Remote Sensing,* **13**, 1391-1412.